

*TRANSFER TESTS OF STIMULUS VALUE IN
CONCURRENT CHAINS*

RANDOLPH C. GRACE AND HERNÁN I. SAVASTANO

UNIVERSITY OF NEW HAMPSHIRE AND
UNIVERSITY OF CALIFORNIA, SAN DIEGO

We report two experiments that use transfer tests to investigate whether in concurrent chains the value of a terminal-link stimulus is affected by the alternate terminal link. In Experiment 1, two groups of pigeons were trained on multiple concurrent-chains schedules in which switching between the schedules was via pecking a changeover key. For one group, the terminal links were fixed-interval 8 s versus fixed-interval 16 s in one component and fixed-interval 16 s versus fixed-interval 32 s in the other component. For a second group, the terminal links were variable-interval 10 s versus variable-interval 20 s in one component and variable-interval 20 s versus variable-interval 40 s in the other. After sufficient baseline training had been given so that performances had stabilized, transfer tests were conducted in which the two chains with equal terminal-link schedules were presented together as a new concurrent pair. For 6 of the 7 subjects, initial-link responding changed fairly rapidly during the test in the manner predicted if the values of the terminal links were equal. In Experiment 2, pigeons were trained on multiple concurrent chains using a two-key procedure, and the terminal links were the same variable-interval schedules as in Experiment 1. After baseline training, transfer tests were conducted that assessed (a) the relative reinforcing strength of the terminal-link stimuli in a novel initial-link situation and (b) the relative ability of those stimuli to evoke responding. The data from the reinforcing strength test were consistent with those from Experiment 1, but those from the evocation strength test were not. Although this discrepancy shows that responding in transfer tests is not solely a function of stimulus value, the results from both experiments suggest, overall, that value is determined by the stimulus–reinforcer relation independently of the alternative terminal link.

Key words: choice, stimulus value, transfer test, context of reinforcement, concurrent chains, key peck, pigeons

Recently there has been increasing interest in the use of transfer tests as an assay of choice. In a transfer test, the effect of baseline training history for a stimulus in a choice situation is assessed by presenting that stimulus in a different situation. Analyzing the responding to one or more stimuli in the test situation may serve to elucidate the variables that control baseline choice and the determiners of stimulus value.

An experiment by Belke (1992) provides a good example. He trained pigeons on a multiple concurrent variable-interval (VI) schedule. In one component, two response keys were illuminated and VI 20-s VI 40-s sched-

ules were in effect, whereas in the other component two different keys were illuminated and VI 40-s VI 80-s schedules were in effect. Components were presented for 1 min, separated by 10-s blackouts, and training continued until response and time allocation approximately matched relative reinforcement rate. Belke then arranged, interspersed with the regular components, nonreinforced transfer test trials in which the keys associated with the two VI 40-s schedules were illuminated for 1 min. Relative response rate in the transfer test was 4:1 in favor of the VI 40-s stimulus that had been presented concurrently with the VI 80-s schedule in training. To explain his results, Belke proposed that stimuli had acquired differential value depending on the context of reinforcement during training. According to this view, the VI 40-s stimulus that had been presented concurrently with the VI 80-s schedule had greater value because it had been the richer alternative in its context, compared with the other VI 40-s stimulus, which had been the leaner alternative in its context. Presumably, re-

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Address correspondence and reprint requests to Randolph C. Grace at the University of New Hampshire, Department of Psychology, Durham, New Hampshire 03824, or Hernán I. Savastano at SUNY Binghamton, Department of Psychology, Binghamton, New York 13902-6000 (E-mail: rcg@christa.unh.edu and hsavasta@binghamton.edu).

sponding during the transfer test reflected this differential value.

Williams (1994) noted that Belke's results posed a strong challenge to both response strengthening and representational accounts of choice. For example, according to both the cumulative effects model (Davis, Staddon, Machado, & Palmer, 1993) and Mazur's (1992) model of choice acquisition (see also Couvillon & Bitterman, 1985), the response strength or value of each alternative increases when a response is reinforced and decreases when a response is not reinforced. These models, like melioration (Herrnstein & Vaughan, 1980), imply that the determiner of value is probability of reinforcement and so predict preference for the VI 40-s stimulus that had been presented concurrently with the VI 20-s schedule. Similarly challenged are models that are based on the assumption that pigeons acquire veridical knowledge of the delays between reinforcers on each alternative (e.g., scalar expectancy theory; Gibbon, Church, Fairhurst, & Kacelnik, 1988), which therefore predict indifference. An explanation for Belke's results is thus important for an understanding of choice. At issue, apparently, is whether or not the theoretical construct that corresponds to learning in a choice situation (i.e., stimulus value or memorial representation) is determined by the context of reinforcement.

Most recently, Gibbon (1995) and Williams and Bell (1996) have replicated and extended Belke's (1992) findings and have provided compelling evidence that his results were caused by a carryover of changeover times established to particular stimuli in baseline. Gibbon (1995) repeated Belke's experiment, except with a switching-key procedure, and presented a modification of scalar expectancy theory that was capable of predicting the results. For this modification he assumed, as Myerson and Miezin (1980) did, that pigeons' behavior on concurrent schedules could be modeled as a stationary two-state Markov process (see also Heyman, 1979). This model implies that changeover probabilities are constant when responding has stabilized so that dwell times on each alternative will be exponentially distributed. Gibbon also assumed that the rate at which pigeons sample remembered delays and decide to stay or switch is determined by level of arousal,

which, in some accounts, is treated as proportional to overall reinforcement rate (Killeen, Hanson, & Osborne, 1978).

Gibbon showed that with these assumptions, his model predicted (and the data confirmed) not only the 4:1 preference in favor of the VI 40-s stimulus that had been presented concurrently with the VI 80-s schedule that Belke found, but also a paradoxical 2:1 preference for the same VI 40-s stimulus when presented concurrently in a transfer test with the VI 20-s stimulus. He found that the distributions of dwell times in baseline and in the transfer tests superposed for each stimulus. In other words, the changeover patterns established during baseline transferred to test, thus producing the predicted pattern of results (see also Mark & Gallistel, 1994). According to Gibbon's analysis, the value of a stimulus (in scalar expectancy theory, its memorial representation) is context invariant, but behavior in the transfer test is affected by the reinforcement context during training.

In their Experiment 1, Williams and Bell (1996) replicated Belke's (1992) study, and then in Experiment 2 used the same procedure except that reinforcer availability on the VI 20-s schedule was signaled. The effect of this signaling was to increase dwell times on the VI 40-s schedule that was presented concurrently with the VI 20-s schedule without changing the overall rates of reinforcement. Consistent with the hypothesis that the pattern of switching behavior established in baseline carried over to the transfer test, the results of the probes were reversed: The VI 40-s stimulus that had been presented concurrently with the signaled VI 20-s schedule engendered a higher rate of responding than the VI 40-s stimulus that had been presented concurrently with the VI 80-s schedule. Williams and Bell (p. 525) noted, however, that if behavior in the transfer test merely duplicated the switching pattern established during baseline, then that behavior could not be used to discriminate between theoretical accounts of choice (apart from underscoring the importance of the switching pattern as a mediator between molar choice and the arranged reinforcement schedules). The implication, surprising perhaps, is that Belke's (1992) results are actually uninformative regarding the question of whether the value of

a stimulus depends on the alternative schedule (i.e., the context of reinforcement).

It is possible that the relationship between stimulus value and reinforcement context may be investigated more effectively using the concurrent-chains procedure. In this procedure, a pigeon responds on concurrently available initial-link schedules to obtain access to mutually exclusive terminal-link schedules of food reinforcement. Choice in the initial links is interpreted as a measure of the relative reinforcing value of the terminal links, or of the effectiveness of the terminal-link stimuli as conditioned reinforcers. An important advantage of concurrent chains over concurrent schedules is that the measure of preference is separate from ongoing behavior during the terminal links. For example, a response bias in favor of the variable-ratio (VR) schedule is obtained with concurrent VI VR schedules (Herrnstein & Heyman, 1979). But this bias does not necessarily imply that the VR schedule has greater value; Herrnstein (1964) found that preference in concurrent chains between VI and VR terminal links was determined by the relative rate of reinforcement, even though response rates during the VR were higher. The implication is that response rate in the presence of a stimulus is not always correlated with the value of that stimulus (see also Williams, 1991). If stimulus value is determined by its context of reinforcement, as Belke (1992) proposed, then results at least qualitatively similar to his should be obtained when the schedules are arranged, not concurrently, but as pairs of terminal links in two concurrent chains, and terminal-link value is assessed through a transfer test.

It is well known that variation in temporal context (i.e., the relative durations of the terminal and initial links) has strong effects on preference in concurrent chains. Such effects have served as the basis for several quantitative models. For example, according to delay-reduction theory (Fantino, Preston, & Dunn, 1993), terminal-link value is a function of the reduction in delay to reinforcement signaled by the onset of a terminal link relative to the overall average interval between reinforcers. Results similar to those of Belke (1992) are predicted by delay-reduction theory for concurrent chains (although the exact magnitude of preference depends on initial-link du-

ration) because the value of the VI 40-s schedule paired as a terminal link with a VI 80-s schedule would be enhanced, relative to the other VI 40-s schedule, by occurring in an overall leaner context of reinforcement. An alternative view is provided by Grace's (1994) contextual choice model, which predicts that the two VI 40-s terminal links should be equally valued. The contextual choice model is based on the generalized matching law (Baum, 1974; Davison, 1983) and incorporates effects of temporal context on terminal-link sensitivity. Value is determined by the delay (or rate) of reinforcement from terminal-link onset, but sensitivity of initial-link choice to differences in value is also modulated by temporal context. The contextual choice model, like scalar expectancy theory, makes a learning-performance distinction: Although context may affect the level of preference obtained, the value of a terminal link is presumed to be determined by the stimulus-reinforcer relation independently of the other terminal link.

We report two experiments that use different types of transfer tests to investigate whether an analogue to Belke's (1992) results is found with concurrent chains. Our experiments are designed to address the question: Is the value of a terminal link, as assessed by transfer tests, a function of the concurrently available schedule during baseline? In both experiments, pigeons received baseline training on a multiple-component concurrent-chains procedure. In one component, the two terminal links that comprised a pair were fixed-interval (FI) 8-s and FI 16-s schedules (or VI 10-s and VI 20-s schedules), whereas in the other component the terminal links were FI 16-s and FI 32-s schedules (or VI 20-s and VI 40-s schedules). Transfer tests that pitted the two FI 16-s (or the two VI 20-s) terminal links against each other were then conducted. The primary question is whether the assumption that terminal-link value is a function of reinforcement context or the assumption that value is independent of reinforcement context provides the better overall account of the transfer test results.

EXPERIMENT 1

Experiment 1 used a changeover-key procedure. Initial links were signaled by red or

green illumination of one of the side keys, and the pigeon could switch between the initial links by pecking the center key. Terminal links were signaled by changing the side key from constant to blinking illumination, coupled with darkening of the center key. For one group of pigeons, the terminal-link schedules were FI 8 s and FI 16 s in one component and FI 16 s and FI 32 s in the other component. For a second group, the terminal links were VI 10 s and VI 20 s, and VI 20 s and VI 40 s. After relative responding in both components had stabilized, the chains for which the scheduled terminal-link reinforcement rates were equal were paired together in a transfer test. In contrast to the probes used by Belke (1992), Gibbon (1995), and Williams and Bell (1996), reinforcement for terminal-link responding continued in the transfer test. If value depends on context, then relative responding during the test should favor the FI 16 s (or the VI 20 s) that was the richer schedule in its component, and, with continued testing, this preference should decrease. If value is independent of context, then responding should be approximately equal on both alternatives. We were also interested in the related question of whether the initial-link dwell-time distributions during the test would be unchanged from baseline, as reported by Gibbon (1995) for concurrent schedules.

METHOD

Subjects

Seven White Carneau pigeons participated as subjects. They were divided into two groups and numbered as follows: Group A: 008, 963, 969, 967; Group B: 026, 027, 973. Pigeons were maintained at 85% ad libitum weight (± 15 g) through appropriate postsession feedings. All had previous experience with a variety of experimental procedures. Subjects were housed individually in a vivarium with a 12:12 hr light/dark cycle (lights on at 7:00 a.m.) and had free access to water and grit.

Apparatus

Four standard three-key operant conditioning chambers were used. The dimensions were 35 cm deep by 35 cm wide by 35 cm high. Response keys were located 26 cm

above the floor. The side keys could be illuminated red or green, and the center key could be illuminated white. A houselight was mounted 7 cm above the center key in each chamber for ambient illumination, and a grain magazine with an aperture (6 cm by 5 cm) was located 13 cm below the center key. A magazine light was turned on when wheat was made available. A force of approximately 0.10 N was required to operate each key, and each response resulted in an audible feedback click. Chambers were enclosed in sound-attenuating boxes and fitted with ventilation fans for masking extraneous noises. The experiment was controlled with a MED-PC® system that was interfaced to an IBM®-compatible microcomputer located in an adjacent room.

Procedure

Because all subjects were experienced, baseline training commenced immediately in a two-component changeover-key concurrent-chains procedure. Each component comprised a separate concurrent chain. Sessions consisted of 12 blocks of six initial- and terminal-link cycles each. All cycles terminated in reinforcement, and successive blocks were separated by a 30-s blackout interval. During baseline, only one of the two components was presented in each block. Components were differentiated by whether the left or right key was used to signal the initial and terminal links, and they strictly alternated over the 12 blocks, with the identity of the first component in each session chosen randomly. The houselight was illuminated at all times except during reinforcement and during the blackouts between blocks. Sessions were conducted 7 days a week at approximately the same time of day.

At the start of a cycle, the side key was illuminated red or green either randomly (for the first cycle of a block) or to match the color of the preceding terminal link (for the remaining cycles of a block). A terminal-link entry was randomly assigned to either the red or green initial link with the restriction that three entries occurred for each initial link during the block. After the first response to the side key, the center key was illuminated white, signaling the availability of a changeover. A response to the center key changed the color of the side key (from red to green or vice versa)

and extinguished the center key, which was reilluminated after the next response to the side key. Although there was a changeover requirement, there was no changeover delay. An initial-link response produced an entry into a terminal link provided that (a) it was to the preselected initial link and (b) an interval sampled at the start of the cycle from a VI 20-s schedule had timed out. The VI 20-s schedule contained 12 intervals constructed from an arithmetic progression, $a, a + d, a + 2d, \dots$, in which a equals one 12th and d equals one sixth of the schedule value. Intervals were sampled randomly without replacement, and separate sampling lists were maintained for each component.

Terminal-link entry was signaled by a change from constant to flashing illumination on the side key (0.25 s off, 0.25 s on), coupled with darkening of the center key (if illuminated). Terminal-link responses were reinforced according to FI schedules (Group A) or VI schedules (Group B). The VI schedules contained 12 intervals constructed from exponential progressions (Fleshler & Hoffman, 1962), and were sampled randomly without replacement. When a terminal-link response was reinforced, the keylight and houselight were extinguished and the grain magazine was raised and illuminated for 2.75 s. After reinforcement, the houselight and the initial-link keylight corresponding to the previous terminal link were reilluminated and the next cycle began, unless the sixth reinforcer in the block had been delivered, in which case a 30-s blackout began.

Baseline training continued until preference in each component was judged to be stable by a visual criterion for all subjects. Then, test sessions were conducted in which the chains that had terminal links with equal reinforcement rates were paired together. For example, suppose that during baseline the terminal links for the left-key component were VI 10 s (red) and VI 20 s (green), and the terminal links for the right-key component were VI 20 s (red) and VI 40 s (green). Then, during a test block, the pigeon would switch in the initial links between the left green key and the right red key. In all other respects, blocks in test sessions remained identical to baseline: The same changeover requirement prevailed, three terminal-link entries were obtained for each initial link,

and a reinforcer was delivered at the end of each terminal link.

Group A. All birds received 33 sessions of baseline training with FI 8-s (red) FI 16-s (green) terminal links for the left-key component and FI 16-s (red) FI 32-s (green) terminal links for the right-key component. Then, three consecutive test sessions were conducted. For the first test session, over the first six blocks the left-key and right-key components alternated, as in baseline, but in the last six blocks the two chains with FI 16-s terminal links were presented as a concurrent pair. The identity of the component in the first block was counterbalanced across birds. There followed two test sessions that consisted entirely of test blocks (12) in which the two chains with the FI 16-s terminal links were arranged as a concurrent pair throughout. Next, 10 additional baseline sessions were conducted, followed by 12 test sessions. As before, the first test session consisted of six baseline blocks and six test blocks, the identity of the first component was counterbalanced across subjects, and all 12 blocks in subsequent test sessions were test blocks. After the 12 test sessions, subjects completed 11 baseline reversal sessions in which the terminal-link schedules were FI 32 s FI 16 s (left key) and FI 16 s FI 8 s (right key).

Group B. All subjects received 31 sessions of baseline training in which the terminal links for the left-key component were VI 10 s (red) VI 20 s (green) and those for the right-key component were VI 20 s (red) VI 40 s (green). Eight consecutive test sessions were then conducted in which the two chains with VI 20-s terminal links were presented as a concurrent pair. As with Group A, the first test session consisted of six baseline and six test blocks, and the identity of the first component was counterbalanced. All 12 blocks in the remaining seven test sessions were test blocks.

RESULTS AND DISCUSSION

Figure 1 shows, for both groups, the logarithm of the initial-link response ratio during baseline for both components. The data were aggregated over the last five sessions preceding both tests and the first six blocks (baseline) of the initial test sessions for Group A and the last five sessions preceding test and the baseline blocks of the initial test session

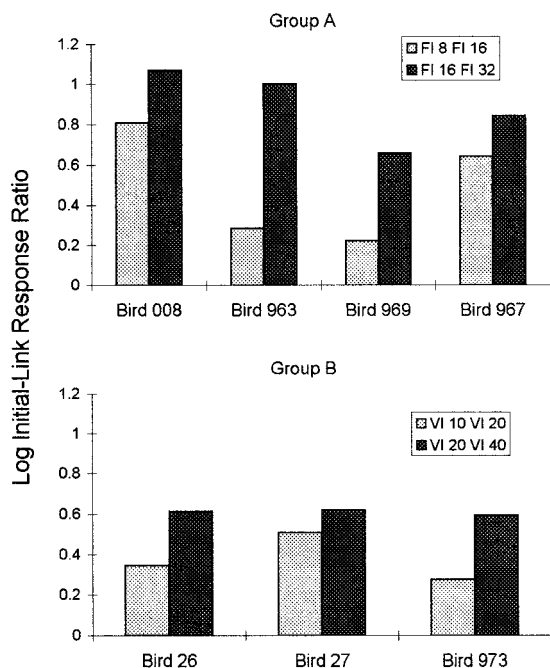


Fig. 1. Baseline preference in each concurrent-chains component for all subjects in Experiment 1. Preference is measured as the logarithm of the initial-link response ratio for the shorter terminal link. A log value of zero indicates indifference (i.e., the log of 1.0 = 0).

for Group B. Data for all subjects demonstrate the so-called *terminal-link effect* (MacEwen, 1972; Williams & Fantino, 1978), in that the preference for the FI 16-s terminal link over the FI 32-s terminal link was greater than the preference for FI 8 s over FI 16 s (Group A); similarly for Group B, preference was greater for VI 20 s over VI 40 s than for VI 10 s over VI 20 s. Absolute preferences were generally higher for Group A than for Group B, consistent with the greater sensitivity to reinforcement delay that is typically found with FI as opposed to VI terminal links (Grace, 1994). Overall, baseline data accord quite well with expectations based on prior research, which suggests that our novel multiple-component changeover-key procedure is a valid technique for exploring, within session, the effects of overall terminal-link duration in concurrent chains.

The primary purpose of Experiment 1 was to examine relative responding for chains with equal initial and terminal links that had been trained in different reinforcement contexts and then were presented as a novel concur-

rent pair. The upper panel of Figure 2 shows, for Group A, the logarithm of the initial-link response ratio for the FI 16-s terminal link that was the leaner alternative in its training context (FI 16L) during the novel-pair tests. The lower panel displays the corresponding data for Group B for the VI 20-s terminal link that was the leaner alternative in its training context (VI 20L). Data are from individual test sessions, and both sets of test sessions for Group A are shown. An analogue to Belke's (1992) results would exist if relative responding strongly favored, at the outset of testing, the FI 16-s (or VI 20-s) schedule that had been the richer alternative in its training context (FI 16R or VI 20R). Because terminal-link schedules continued to operate normally, the magnitude of such an effect ought to have decreased over subsequent test sessions.

However, the data in Figure 2 provide little evidence for a concurrent-chains analogue to Belke's (1992) results. For the first set of test sessions for Group A, relative initial-link responding for all subjects was near indifference (i.e., near a log ratio value of zero) or slightly in favor of FI 16R, and shifted in favor of FI 16L over the three sessions. For the second group of 12 test sessions, Bird 967 showed a small preference for FI 16L in the first session, which increased dramatically over subsequent sessions, whereas Bird 008 had a small preference for FI 16R, which also increased dramatically. Relative responding for Bird 963 cycled below and above indifference and remained near indifference throughout for Bird 969. For Group B, relative responding for Bird 027 strongly favored the VI 20R terminal link across test sessions, whereas it slightly favored VI 20L and VI 20R for Birds 973 and 026, respectively. Overall, the data in Figure 2 are highly variable across subjects and sessions. It is clear, however, that a strong preference early in testing for FI 16R and VI 20R, which declined over sessions towards indifference, was not reliably obtained.

Although molar preference showed no consistent pattern across subjects in Figure 2, it is possible that order could emerge if data are examined at a more local level. Figures 3 through 5 show the normalized dwell-time distributions for initial-link responding during baseline and test sessions, plotted on semilogarithmic coordinates, for both groups. A dwell time is defined as the duration that the initial-

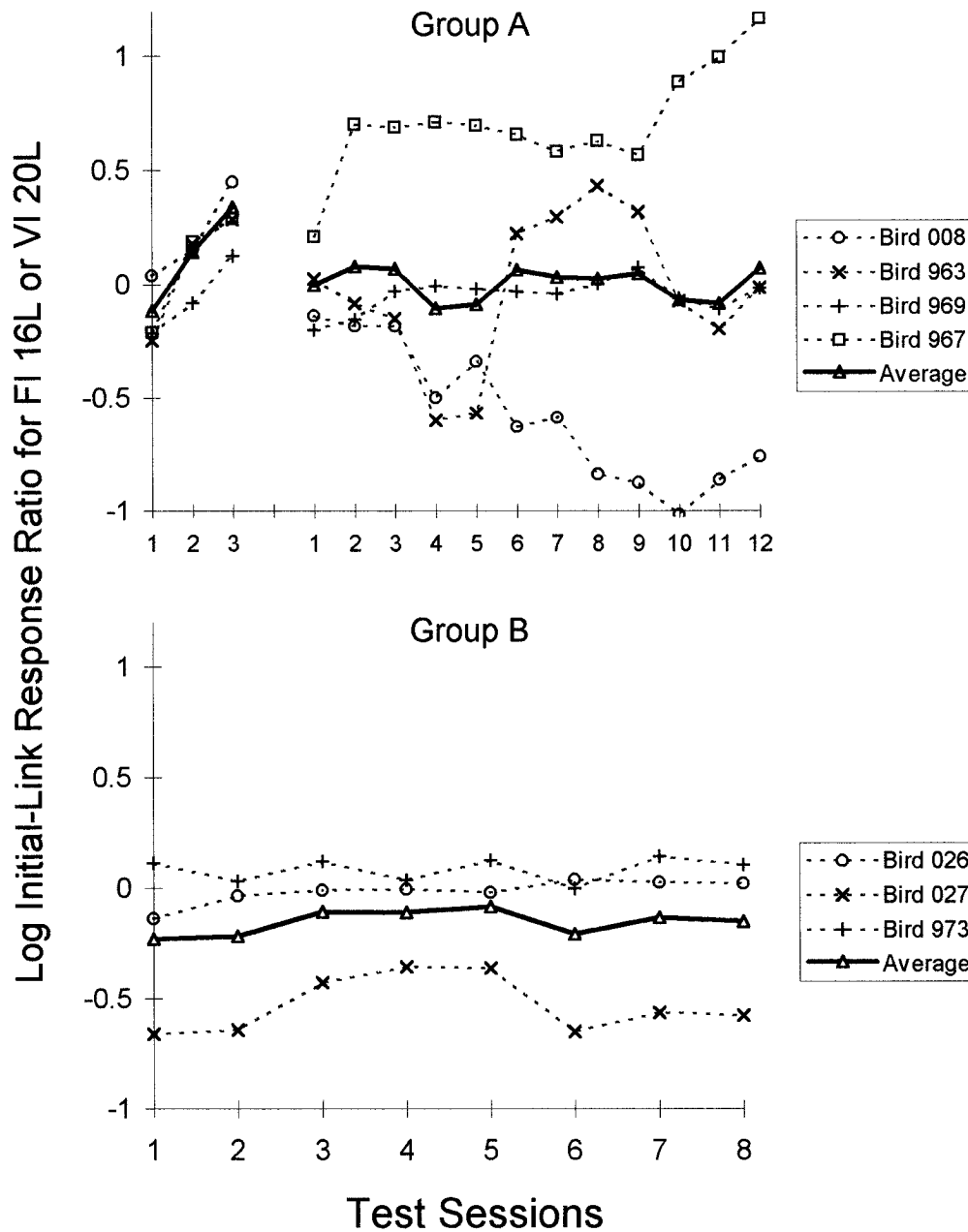


Fig. 2. For all subjects in Experiment 1, the logarithm of the initial-link response ratio during the test sessions. Responses for the alternative that had been learner in its training context (FI 16L or VI 20L) are in the numerator. Data for individual subjects are marked as noted in the legends.

link stimulus was illuminated for responding; dwell times could begin either with the start of a cycle or a changeover and could end either with changeover or terminal-link entry. Frequency distributions were tabulated for dwell times and normalized by calculating the

relative probability of occurrence for each bin. The bin size was 1.5 s for Group A and 0.5 s for Group B. Figure 3 shows the dwell-time distributions for Group A for the first set of three consecutive test sessions; similar data for the second set of 12 consecutive test sessions

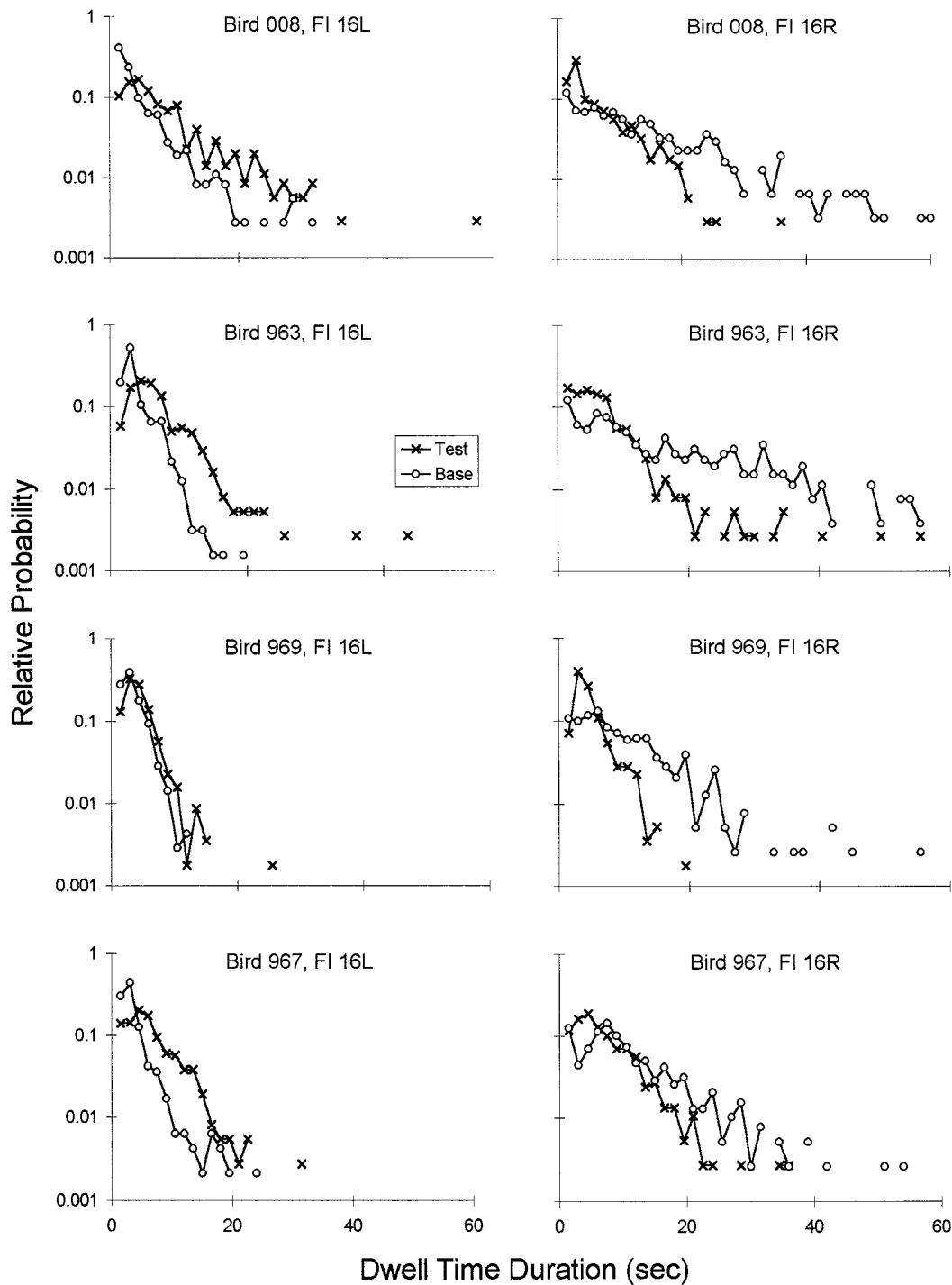


Fig. 3. Normalized dwell-time frequency distributions for all Group A subjects in Experiment 1 for the first set of three test sessions and preceding baseline. The left panels show data for responding in the initial link that preceded the FI 16-s terminal link that was the leaner alternative in its training context (FI 16L); the right panels show the corresponding data for the FI 16-s terminal link that was the richer alternative in its training context (FI 16R). Data from test sessions are marked with Xs; data from the preceding baseline are marked with open circles. The occasional gaps were produced by empty bins.

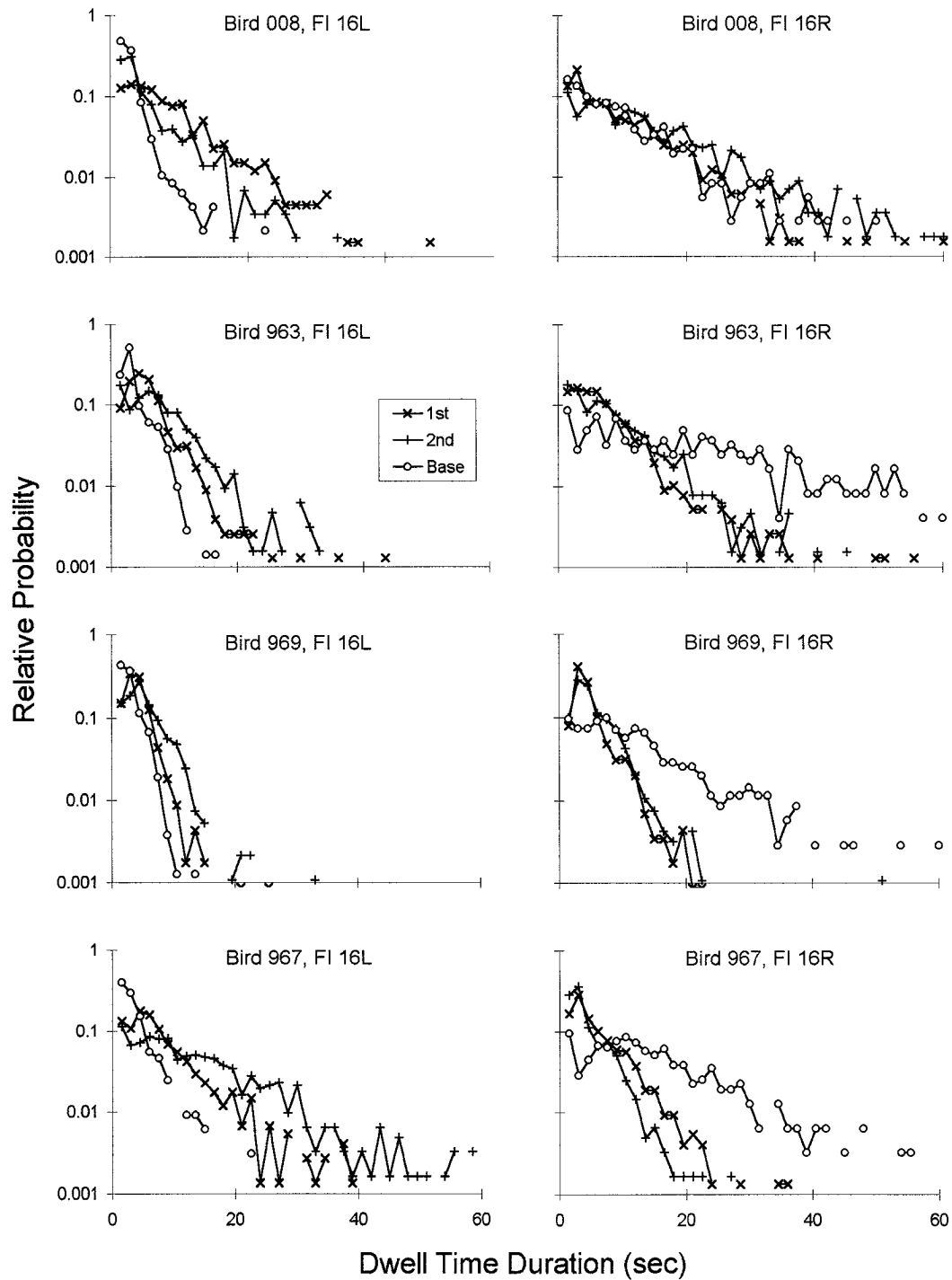


Fig. 4. Normalized dwell-time frequency distributions for all Group A subjects in Experiment 1 for the second set of 12 test sessions and preceding baseline. The left panels show data for responding in the initial link that preceded the FI 16-s terminal link that was the leaner alternative in its training context (FI 16L); the right panels show the corresponding data for the FI 16-s terminal link that was the richer alternative in its training context (FI 16R). Data from the first four test sessions (1st) are marked with Xs; data from the last four test sessions (2nd) are indicated by crosses; data from the preceding baseline are shown as open circles. The occasional gaps were produced by empty bins.

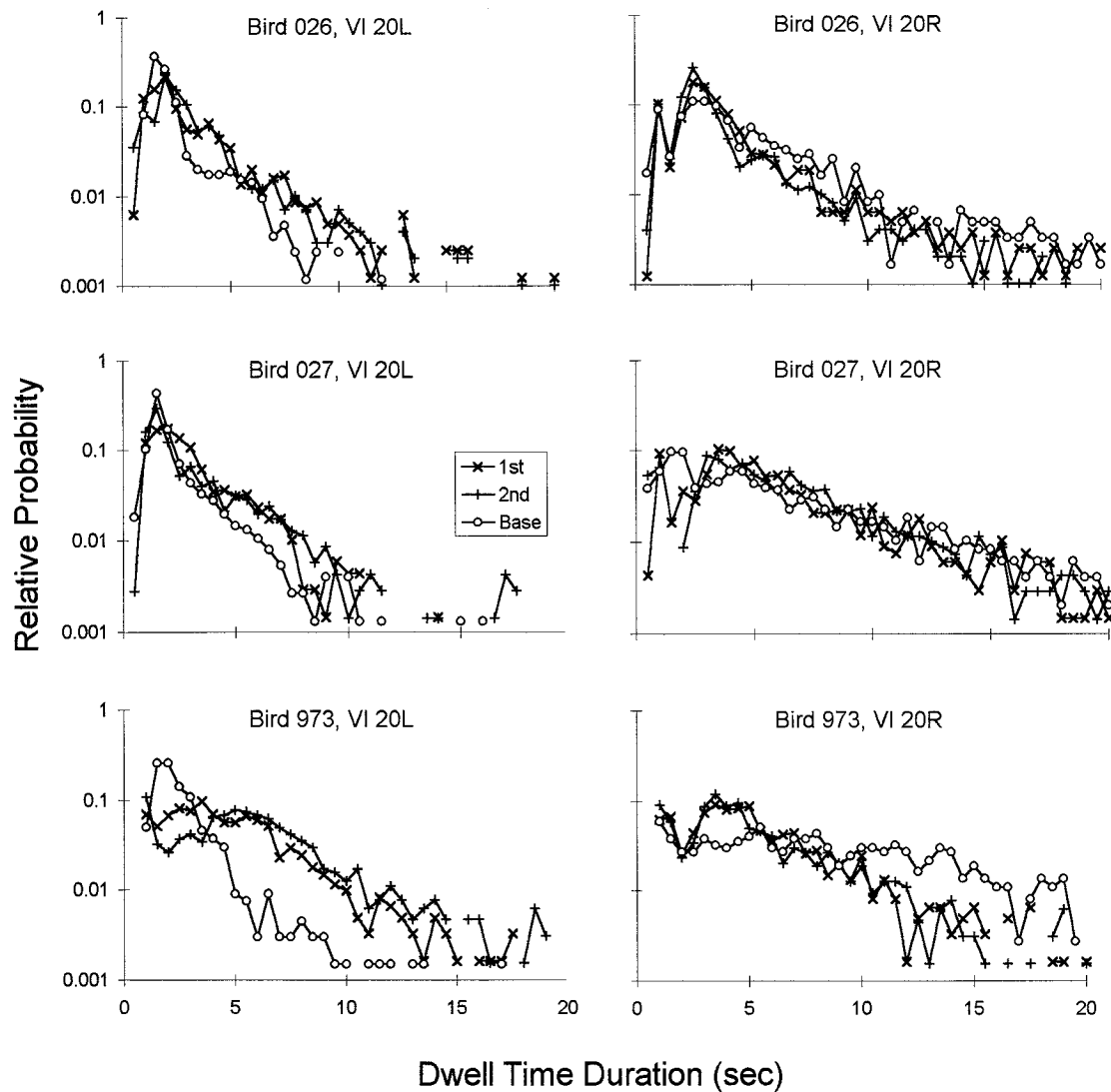


Fig. 5. Normalized dwell-time frequency distributions for all Group B subjects in Experiment 1 for the set of eight test sessions and preceding baseline. The left panels show data for responding in the initial link that preceded the VI 20-s terminal link that was the leaner alternative in its training context (VI 20L); the right panels show the corresponding data for the VI 20-s terminal link that was the richer alternative in its training context (VI 20R). Data from the first four test sessions (1st) are marked with Xs; data from the last four test sessions (2nd) are indicated by crosses; data from the preceding baseline are shown by open circles. The occasional gaps were produced by empty bins.

are presented in Figure 4. Figure 5 shows the dwell-time distributions for Group B. In all cases, baseline data were taken from the five sessions that preceded the particular set of test sessions.

In general, the distributions have the same shape that Gibbon (1995) found for concurrent schedules: a sharp increase over the shortest bins (in some cases), followed by an

approximately linear decrease. Although Gibbon suggested that the initial increase might have been due to a changeover delay (COD), the present experiment did not use a COD, so the increase most likely represents an effective minimum stay duration. (It is notable in this regard that increases were most readily observed for Group B in Figure 5, where 0.5-s bins were used.) The comparability of the

concurrent-chains dwell-time distributions to those obtained with concurrent schedules suggests that switching behavior in both procedures may be controlled by the same process, and that process, apart from the increase for the shortest bins, is stochastic and is well described as a stationary Markov process (i.e., the probability of switching out of each initial link is constant). This comparability is consistent with Herrnstein's (1964) proposal that conditioned and unconditioned reinforcers are functionally equivalent in their effects on choice, which is necessary for the matching law to apply both to concurrent schedules and to concurrent chains (Grace, 1994; see also Williams & Dunn, 1991).

In Group A, all subjects demonstrated the same pattern for the first set of three test sessions (Figure 3): Compared with baseline, the slope of the distribution for responding on the alternative that had been leaner in its training context (FI 16L) became flatter, whereas the slope of the distribution for responding on the alternative that had been richer (FI 16R) became steeper (note that steeper slopes indicate higher changeover probabilities and vice versa). These changes for FI 16L and FI 16R are in the direction that suggests that the values of the two alternatives were equal during the test. Figure 4 shows that this pattern was replicated in the first four of the set of 12 consecutive test sessions for 3 subjects (Birds 963, 967, and 969). For Bird 008 the slope for FI 16R did not become steeper, although the slope for FI 16L flattened as before.

Comparing the slopes for the first and last sets of four test sessions in Figure 4 indicates whether systematic changes in switching occurred over the course of more extended training for Group A. For 3 subjects (Birds 963, 967, and 969), the slope for FI 16L continued to flatten over the final four test sessions, whereas for Bird 008 the slope for FI 16L became steeper. The slope for FI 16R flattened for Bird 008, steepened for Bird 967, and remained approximately constant for Birds 963 and 967. Both the flattening for Bird 008 and the steepening for Bird 967 are consistent with the systematic changes in relative response rate over the test sessions for these birds. Thus, the between-subject variability shown in the upper panel of Figure 2

corresponds to differences in how switching patterns adjusted throughout testing.

For Group B (Figure 5), the slope for the alternative that had been leaner in its training context (VI 20L) flattened in the first set of test sessions for all subjects, consistent with Group A. However, only 2 of 3 subjects (the exception was Bird 027) showed a corresponding steepening for VI 20R, and only marginally so for Bird 026. Also in contrast with Group A is the fact that only 1 subject (Bird 973) showed a further flattening in the slope for VI 20L in the second set of sessions. This might have occurred because Group B received only eight consecutive test sessions, compared with 12 for Group A.

For all subjects in both groups, therefore, the slope of the dwell-time distribution for the alternative that had been leaner in training flattened during the first test sessions. This stands in sharp contrast to Gibbon's (1995) results with concurrent schedules—namely, that the dwell-time distributions from test sessions were unchanged from baseline for both previously richer and leaner alternatives. However, the changes we observed were not completely symmetrical: Although the slopes for the previously leaner alternative always changed in the same direction, corresponding changes in the slopes for the previously richer alternative occurred less reliably, especially for the VI schedules. If relative response rate during the tests had been completely controlled by scheduled terminal-link delays to reinforcement, then these changes should have been symmetrical. But a clear steepening for the previously richer alternative was obtained for only 1 subject with VI terminal links (Bird 973); a 2nd subject (Bird 026) showed a marginal effect in the same direction. In contrast, with FI terminal links (Group A), the slope steepened for all subjects in the first set of test sessions and for 3 of the 4 subjects in the second set of test sessions. Overall, these data suggest that changes in slope occur more readily for the previously leaner alternative, and occur more readily with FI than with VI terminal links. The latter result is consistent with Mellon and Shull's (1986) finding that initial-link response strength, as measured by resistance to change, is generally lower with FI than with VI terminal links.

Regardless of these asymmetries, for all

subjects with FI terminal links and 2 of the 3 subjects with VI terminal links, ordinal changes in dwell-time distribution slopes occurred in the first few sessions of the novel-pairs test, consistent with the hypothesis that terminal-link value was determined by the scheduled rates of reinforcement and was independent of the other terminal link. However, alternative explanations need to be considered. We will examine two here: (a) that the changes represented a breakdown in established response patterns, not control by the scheduled reinforcement rates, and (b) that the changes occurred because the terminal links continued to operate normally in the transfer test.

One factor that may have contributed to our failure to find unchanged switching patterns in the test, in contrast with Gibbon (1995), is that the control exerted by initial-link stimuli over responding is weaker than that exerted by concurrent-schedules stimuli, which are temporally contiguous with reinforcement. Any tendency for baseline response patterns to carry over to the test should therefore be more pronounced with concurrent schedules. Supporting this notion are the results of Nevin, Mandell, and Yarowsky (1981), who found that response strength in chain schedules, as measured by resistance to disrupters such as satiation and extinction, was greater in the terminal link than in the initial links. If the novel-pairs test is construed as a disrupter, it should decrease responding in concurrent chains more readily. Perhaps, then, the shifts in dwell-time distributions reflect a breakdown in established response patterns only and not an adaptation to the new choice situation (in more colorful terms, the pigeons might have been "confused" by the sudden introduction of the novel pair). If so, then overall initial-link response rate should have decreased during the test. To investigate this possibility, these rates were calculated for each subject for the test blocks in the first test session and were compared with rates during the preceding baseline (i.e., preceding five sessions and first six blocks of the test session). The data are shown in Table 1. To the extent that the introduction of novel pairs functioned as a disrupter, response rates during the test should have decreased relative to baseline. However, changes between baseline and the test were

Table 1

A comparison of overall initial-link response rates during baseline and the first transfer test session. Rates (responses per minute) were calculated separately for the preceding five baseline sessions and the first six blocks of the first test session (baseline), and last six blocks of the first test session (test).

	Bird	Baseline	Test
Group A	008	34.66	47.74
	963	21.44	33.35
	969	29.05	24.12
	967	39.88	40.79
Group B	026	51.08	42.09
	027	32.03	40.87
	973	29.35	44.47
	Average	33.93	39.06

unsystematic, with decreases occurring for only 2 of 7 subjects. This outcome suggests that the shifts in dwell-time distributions cannot be attributed to a general deterioration of responding.

A second possible alternative explanation concerns the method in which our transfer tests were arranged. Belke (1992), Gibbon (1995), and Williams and Bell (1996) presented 1-min test trials in extinction, interspersed with baseline training. Over the course of testing, their pigeons received a total of 20 (Belke), 40 (Gibbon), and 24 (Williams & Bell) min of exposure to the novel pair. In our transfer test, terminal-link reinforcement was maintained and there was no additional baseline training. The average obtained initial-link time was approximately 15 min for the first test session and 30 min for each session thereafter (arranged times were 12 and 24 min, respectively). Thus, the dwell-time distributions during the test, shown in Figure 3 (Group A), represent about 75 min of exposure to the novel pair. It is conceivable that the shifts in the distributions represent the effects of reinforcement during the test, and not prior training. To exclude this possibility, we need to demonstrate that baseline response patterns changed quickly in the first test session, more rapidly than changes produced by reversing the terminal-link schedules (i.e., altering the stimulus-reinforcer relations).

Figure 6 shows the cumulative number of responses made to each initial-link stimulus in the transfer test, for each of the 36 cycles in the first test session. The squares indicate

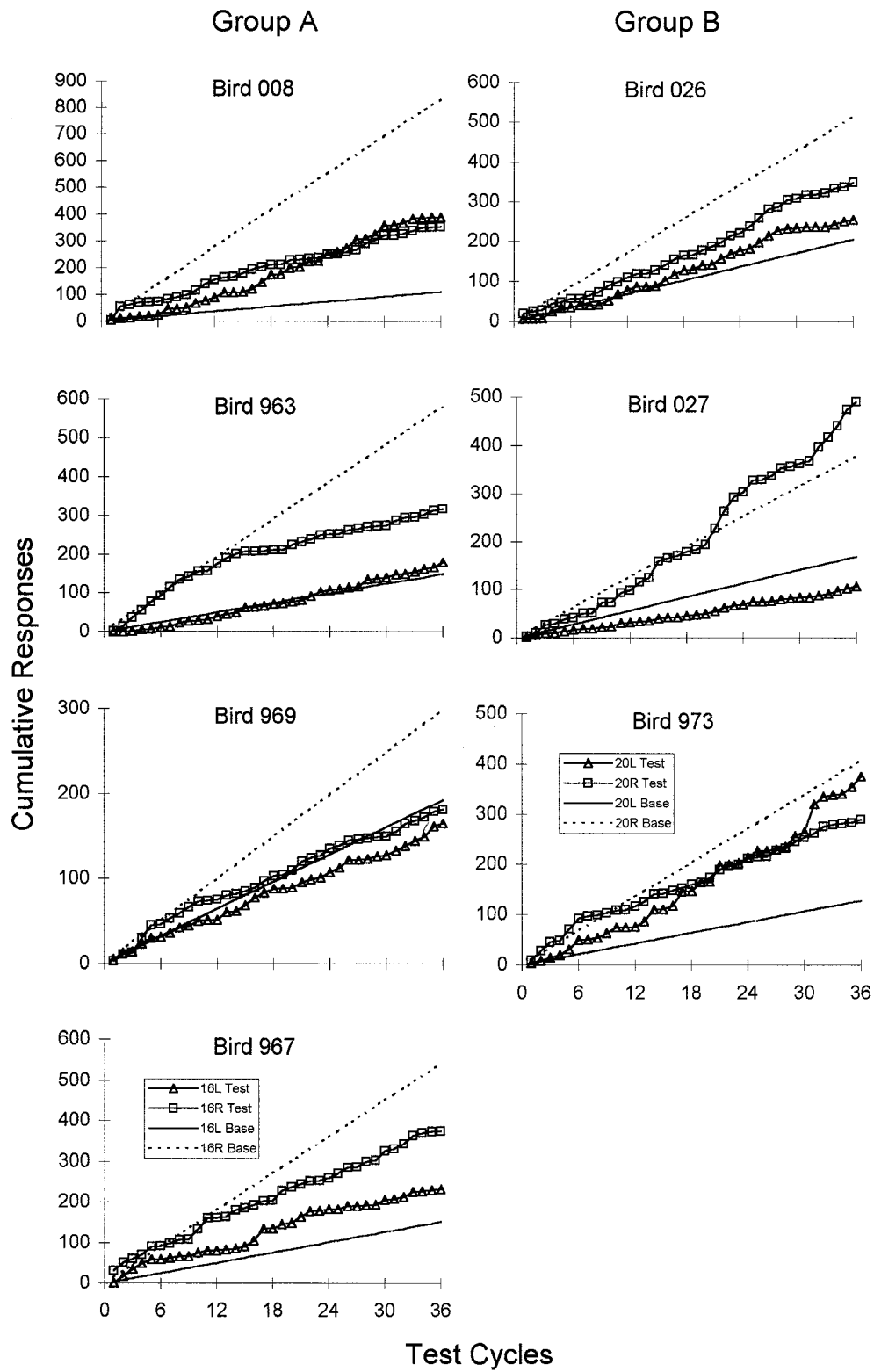
responses to the previously richer alternative (FI 16R or VI 20R); the triangles indicate responses to the previously leaner alternative (FI 16L or VI 20L). The dashed and solid lines represent the number of responses that would have been made to the previously richer and leaner alternatives, respectively, given that responding to that key continued at the baseline rate. Thus, comparing relative slopes across the cycles of the cumulative response functions with baseline indicates if and when preference changed in the first test session, compared with that predicted by a carryover of baseline response rates.

Consider first the data for Group A. For Bird 008, responses per cycle on FI 16R decreased after the second cycle, compared with baseline, whereas responses per cycle on FI 16L increased after about the ninth cycle. At the end of the session the response totals for each alternative were about equal. For Bird 963, responses per cycle closely corresponded to baseline for the first 14 cycles, but then responding on FI 16R abruptly decreased so that responses per cycle for both alternatives were approximately equal for the rest of the session. Responses per cycle for both alternatives decreased for Bird 969 around the 10th cycle, but decreased relatively more for FI 16R so that response totals by the end of the session were almost equal. For Bird 967, responses per cycle increased for FI 16L after the second cycle and decreased for FI 16R somewhat later. Thus, although there were individual differences in how responding changed, for all subjects in Group A changes occurred in the first test session in the direction predicted if the values of the terminal links were equal. For Group B, changes similar to those of Group A were observed for Birds 026 and 973. Also, an abrupt decrease in responding on VI 20R, similar to that of Bird 963, occurred for Bird 973 after the sixth cycle. However, responses per cycle for Bird 027 changed in the opposite direction, so that by the end of the session preference in favor of VI 20R was more extreme than predicted by baseline.

The data in Figure 6 suggest that there was a tendency at the start of the transfer test for baseline response patterns to be maintained, but that in general (the only exception being Bird 027) responding shifted fairly rapidly so that by the 15th cycle or so (approximately 6

min exposure), relative responses per cycle were approximately equal. The magnitude of the carryover or hysteresis effect differed across birds, and in some cases differed between schedules for the same bird (e.g., Birds 008 and 963).

To conclude that the rapidity of the preference change shown in Figure 6 is due to prior training and not to reinforcement during test, it is necessary to demonstrate that these changes occurred more rapidly than those that are produced by altering the stimulus-reinforcer relations. Following completion of the second set of transfer test sessions, Group A received 11 baseline reversal sessions in which the terminal links were FI 32 s FI 16 s (left key component) and FI 16 s FI 8 s (right key component). For each component, we calculated the proportion of predicted eventual change in preference attained in each session as the difference between baseline and session preference divided by the difference between baseline and predicted asymptotic preference (which was assumed to equal the negative of baseline preference in the other component). All preference measures were expressed as log ratios. In the first session following the reversal, the proportions of predicted eventual change, averaged across components for each bird, were as follows: Bird 008, 0.12; Bird 963, 0.24; Bird 969, 0.20; Bird 967, 0.29. For the 11th session, the corresponding attained proportions were 0.29, 0.44, 0.29, and 0.60. These values may be compared with the proportions of predicted eventual change that were attained in the first test session (defining baseline preference as the log ratio of baseline response rates to FI 16R and FI 16L, and assuming indifference at asymptote): 1.05, 0.58, 0.79, and 0.62. For all birds, a greater relative change in preference was achieved after a single test session (36 cycles) than after 11 sessions (72 cycles each) in which the terminal links were reversed. Thus, it is clear that the rapid changes in preference shown in Figure 6 cannot be ascribed to the effects of reinforcement during the transfer test. Instead, subjects (with the exception of Bird 027) were able to respond quickly to the novel pair in a way that was consistent with extensive training with that pair as a baseline itself. The implication is that these rapid changes reflected the values of the ter-



minal-link stimuli established in baseline, which were determined by the stimulus–reinforcer relations and hence were equal and independent of reinforcement context. The relative sluggishness with which preference changed following the baseline reversal, compared with the rapidity of change in the transfer test, is consistent with this view: The stimulus–reinforcer relations were altered in the baseline reversal but were preserved in the transfer test.

The rapid changes seen in Figure 6 indicate greater control during test by the scheduled rates (or delays) of reinforcement, compared with the concurrent VI VI data of Gibbon (1995) and Williams and Bell (1996). There is a sense in which this is paradoxical, in that a given rate of reinforcement was more effective in controlling behavior in a transfer test when that rate was temporally distant from responding. Control by scheduled reinforcement rates, however, will avoid the maladaptive preference in favor of an alternative with the lower rate that Gibbon (1995) reported (VI 40 s over VI 20 s). Because a more adaptive choice is obtained when the consequences of responding are delayed from the choice point, our results resemble the phenomenon of self-control, in which choice for a larger, more delayed reinforcer over a smaller, more immediate reinforcer increases as delays to both reinforcers increase (Rachlin & Green, 1972). There is a difference, though, because both impulsivity (i.e., choice for the smaller, more immediate reinforcer) and self-control can be conceptualized as choice for the higher valued alternative, where value is determined jointly by amount and delay of reinforcement. In contrast, according to the contextual choice model and scalar expectancy theory, the values of the alternatives with equal scheduled reinforcement rates in Experiment 1 and in the experiments of Belke (1992), Gibbon (1995), and Williams and Bell (1996) are equal, despite the fact that the transfer test results were different.

A remaining puzzle, however, is why rela-

tive response rates for Birds 008 and 967 diverged dramatically over the course of the second set of test sessions (see Figure 2, upper panel). One possibility is the development of position biases. Whatever their origin, the fact that the changes for these birds were gradual strongly suggests that they were the result of continued exposure to the test situation and did not reflect differences in stimulus value that were established in baseline.

To summarize, Experiment 1 demonstrated that when pigeons were trained on two separate concurrent chains in baseline and then were confronted with a novel concurrent chain consisting of two equal chains, one of which had been preferred and one of which had not been preferred in baseline, the initial-link dwell-time distributions generally shifted in the direction predicted if the values of the terminal-link stimuli were equal (i.e., independent of reinforcement context). Although not immediate, the shifts occurred by the 15th test cycle at the latest. Our failure to find substantial carryover of baseline dwell times contrasts sharply with the concurrent-schedules data of Gibbon (1995). In addition, our data are not vulnerable to Williams and Bell's (1996) observation that the carryover found in their study and that of Gibbon implies that those data cannot discriminate between theoretical accounts of choice. Overall, the results of Experiment 1 are consistent with the view espoused by the contextual choice model and scalar expectancy theory, that value is determined by the stimulus–reinforcer relation and is independent of the alternative terminal link.

EXPERIMENT 2

Although they are consistent with the hypothesis that value is independent of reinforcement context, the results of Experiment 1 are insufficient to rule out the opposing view that value depends on context. The major problem with Experiment 1 is that the transfer tests may not have been sufficiently

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Fig. 6. For all subjects in Experiment 1, cumulative responses to each alternative per test cycle in the first test session. The left column contains data for Group A; the right column contains data for Group B. See text for more explanation.

sensitive to detect what might have been a small effect of context on value. For example, it is possible that an increase in relative value due to context for the alternative that had been richer in baseline was less than the preference predicted by a full carryover of baseline response rates. If so, then the shifts in dwell times might have occurred because relative value in the transfer test was less than that predicted by carryover but still in favor of the previously richer alternative. Although this seems unlikely because, after an initial period of adjustment, relative response rates were approximately equal for 6 of the 7 subjects in the first transfer test session (see Figure 6), a more stringent test requires that additional, independent measures of stimulus value be taken. Our approach is to employ converging operations to measure value, and then to determine which theoretical interpretation best accounts for the results in their entirety (Garner, Hake, & Eriksen, 1956).

In Experiment 2, we again used a multiple-component concurrent-chains procedure. In one component the terminal links were VI 10 s VI 20 s, and in the other the terminal links were VI 20 s VI 40 s. Unlike Experiment 1, which used a changeover-key procedure, Experiment 2 employed a two-key procedure. Each terminal link was signaled by a different solid color (red, yellow, green, or blue), and a white X was superimposed to signal the corresponding initial link. In this way, the impact of position bias on preference was minimized by randomly selecting the spatial position of each chain at the start of a cycle.

After baseline performances had stabilized, several transfer tests were conducted, which were of two different types. In the first type, the relative conditioned reinforcing effectiveness of a novel pair of terminal-link stimuli was assessed by making their presentation contingent on responding in a novel initial-link situation (*reinforcing strength* test). In the second type, the relative responding evoked or elicited by a novel pair of terminal-link stimuli was assessed by presenting them simultaneously as a choice probe (*evocation strength* test). Unlike Experiment 1, extinction was in effect during all transfer tests.

METHOD

Subjects

Four White Carneau pigeons (G9, G15, G36, and G10) served as subjects. All birds

had participated in previous concurrent-chains experiments. The birds were maintained at 80% of their free-feeding weights (± 20 g). Water and grit were freely available in the home cages, which were located in a room with regular day-night cycles. Sessions were typically conducted in the morning, 6 days a week.

Apparatus

Four standard experimental chambers (32 cm long, 28 cm wide and 32 cm high) were used. Three plastic response keys, each 2.5 cm in diameter, were mounted on the front wall, 23 cm above the wire-mesh floor. A force of approximately 0.1 N was required to operate each key and to produce audible feedback. Visual stimuli were projected onto each key with an IEE 12-bulb projector mounted behind the front wall. A hopper located below the center key provided access to mixed grain, during which a 6-W bulb illuminated the hopper. Another 6-W light was mounted on the ceiling and provided ambient lighting when grain was not available. Each chamber was enclosed in a light-attenuating wooden box that contained a small fan for ventilation and masking of extraneous sounds. In an adjacent room, an IBM®-compatible computer controlled the presentation of stimuli and recorded responses via custom-made interfacing.

Procedure

Concurrent chains. Each session began with the onset of the houselight and side-key stimuli signaling the availability of independent, concurrent VI 40-s VI 40-s initial-link schedules. A 2-s COD operated during the initial links. Completion of either initial link produced a terminal-link schedule and corresponding stimulus on the same key, while the other key was darkened. Responding during the terminal links was reinforced according to separate VI schedules by 4 s of access to mixed grain, after which the initial links were reinstated and the next cycle began. Each terminal link was signaled by a color stimulus (red, yellow, green, or blue). The corresponding initial link was signaled by a white X that was superimposed on the color. The position of the initial links was determined randomly at the start of each cycle to control for position bias. All VI schedules were con-

structed from geometric progressions and consisted of 15 intervals (Fleshler & Hoffman, 1962). Intervals were selected randomly without replacement.

Baseline training. Pigeons received baseline training in a two-component concurrent-chains procedure. Components alternated in blocks of 10 cycles that were separated by a 30-s blackout. The first component was selected randomly at the start of each session. The components differed in terminal-link duration: In one component, VI 10-s and VI 20-s terminal links operated, and in the other component VI 20-s and VI 40-s terminal links operated. Assignment of colors to each chain was counterbalanced across birds. Baseline sessions ended when 60 cycles had been completed. Training in baseline continued for a minimum of 18 sessions, after which performance was checked for stability. Performance was judged to be stable if relative initial-link responding (measured as a proportion) in both components satisfied the following criteria: (a) The means of each three-session block from the preceding nine sessions did not differ by more than $\pm .07$ and (b) neither a monotonic increasing or decreasing trend was obtained over the three blocks. Responding was judged to be stable after 22 sessions for Bird G36 and after 23 sessions for the other birds.

Transfer tests. There were four transfer tests (T1, T2, T3, and T4). Each test began after baseline responding had stabilized, and the tests were presented in the same order for all subjects. Each test lasted for one session and was followed by eight sessions of additional baseline training. During a test session, three blocks of test cycles were interspersed among the baseline components. Each block consisted of 10 cycles, starting at the 20th, 40th, and 60th baseline cycles. Thus, test sessions lasted 90 cycles, 30 of which constituted the transfer test. All test cycles ended in a 4-s blackout (extinction).

The first two tests (T1 and T2) measured the extent to which the conditioned reinforcing efficacy of a novel pair of terminal-link stimuli would transfer to a different initial-link context (reinforcing strength tests). The initial links were signaled by white Xs with no color background. A single VI 30-s schedule operated. Once an interval had elapsed, either the left or right alternative was selected

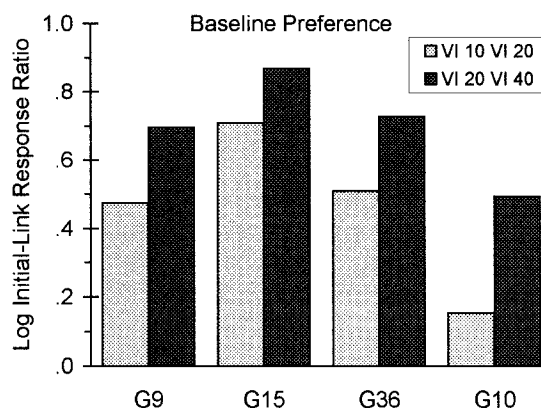


Fig. 7. Baseline preference in each concurrent-chains component for all subjects in Experiment 2. Preference is measured as the logarithm of the initial-link response ratio.

randomly, with the constraint that each occurred twice in every four cycles, and the next response to that key produced a terminal link. During the first two transfer tests, all terminal-link schedules were VI 20 s, but the stimuli were varied. For T1, the terminal-link (i.e., test) stimuli were the two VI 20-s terminal-link stimuli from baseline training. For T2, the test stimuli were the VI 10-s and the VI 40-s stimuli from baseline. The side leading to each test stimulus was counterbalanced across birds.

The next two tests (T3 and T4) measured the relative responding evoked by a novel pair of terminal-link stimuli, presented simultaneously as in a choice probe (evocation strength tests). The test stimuli were presented on the side keys, and a single VI 30-s schedule operated. When an interval had elapsed, the left or right alternative was selected randomly and the next response to that key ended the test cycle. For T3, the test stimuli were the VI 20-s terminal-link stimuli. The position of the test stimuli was counterbalanced across birds. T4 was a replication of T3, with the position of the stimuli reversed for each bird.

RESULTS AND DISCUSSION

Baseline preferences for each bird are shown in Figure 7. Preference is scaled as the logarithm of the initial-link response ratio for the shorter (preferred) terminal link in each component. The data are averaged across the last nine baseline sessions. As in Experiment

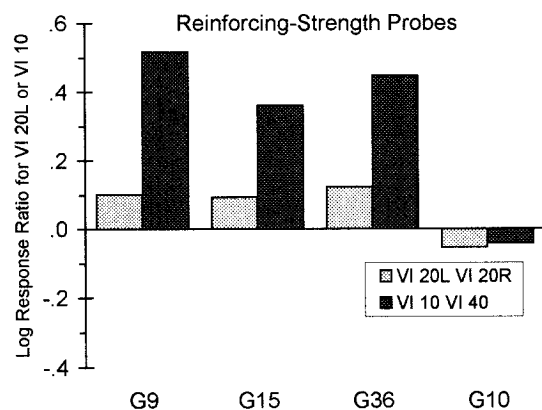


Fig. 8. The logarithm of the initial-link response ratio in the reinforcing strength tests (T1 and T2) for all subjects in Experiment 2. The light gray bars are the T1 data; the dark gray bars are the T2 data.

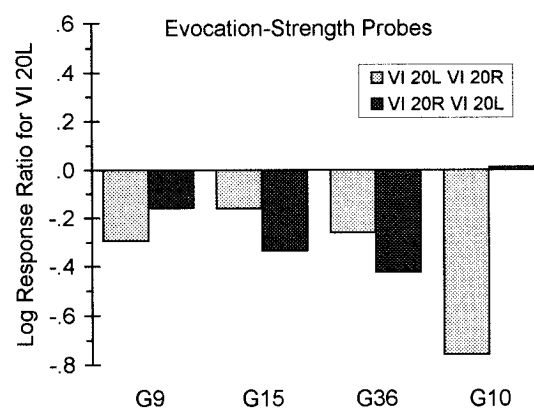


Fig. 9. The logarithm of the response ratio in the evocation strength tests (T3 and T4) for all subjects in Experiment 2.

1, all birds demonstrated the expected effect of terminal-link duration: Preference was more extreme with longer absolute durations. In the VI 10-s VI 20-s component, individual preferences (logs of the ratios) were 0.47 (G9), 0.71 (G15), 0.51 (G36), and 0.15 (G10). In the VI 20-s VI 40-s component, preferences were 0.70 (G9), 0.87 (G15), 0.73 (G36), and 0.49 (G10). Because our concurrent-chains procedure was unconventional, particularly in the stimulus arrangement and that the spatial position of each chain was selected randomly on every cycle, it is reassuring that the usual effect of terminal-link duration was replicated.

Figure 8 shows data from the reinforcing strength tests (T1 and T2) for each bird. Although each test session contained 30 test cycles, the data presented here exclude the first four cycles to allow for exposure to the contingencies. For T1 (VI 20L VI 20R), log response ratios for the VI 20-s stimulus paired with the VI 10-s schedule during baseline (VI 20L) are given. For T2 (VI 10 VI 40), log response ratios for the VI 10-s stimulus are given. For all birds, responding in T1 was close to indifference. One bird (G10) displayed a slight preference (-0.06) for VI 20R, whereas the other 3 birds had marginally greater preferences for VI 20L: 0.10 (G9), 0.09 (G15), and 0.12 (G36). That these data approximate indifference suggests that the two VI 20-s terminal-link stimuli were about equally reinforcing in the test.

Data from T2 confirm that this indiffer-

ence was not merely the result of an insensitive test: The average log response ratio for the VI 10-s stimulus over the VI 40-s stimulus was 0.32. This preference was clearly obtained for 3 birds, 0.52 (G9), 0.36 (G15), 0.45 and (G36). The exception was Bird G10, whose data were close to indifference. Overall, given the assumption that transfer of conditioned reinforcing efficacy to a novel initial-link situation is a valid index of stimulus value, data from T1 and T2 suggest that stimulus value was determined by the scheduled terminal-link delays to reinforcement and was unaffected by the alternative schedule during baseline.

Data for the evocation strength transfer tests (T3 and T4) are presented in Figure 9. Data from all test cycles were included for this analysis. In both T3 and T4 relative responding favored, for 3 subjects, the VI 20-s stimulus that had been paired with the VI 40-s schedule in training. This preference is in the same direction as that found by Belke (1992). Because stimulus position was reversed for T4 and colors were counterbalanced, this result cannot be attributed to bias. The only exception in eight determinations was found, once again, for Bird G10, whose data showed indifference. However, perhaps this bird's data should be weighted less heavily because they were clearly anomalous in all four tests, and because the bird stopped eating suddenly and died shortly after completion of Experiment 2. We suspect that Bird G10 had been ill throughout.

In any case, it is clear that the reinforcing

strength and evocation strength test data are in conflict: In T1, approximate indifference was obtained between the two VI 20-s stimuli, whereas in T3 and T4 relative responding favored the VI 20-s stimulus that had been paired with the VI 40-s schedule. If stimulus value is a valid construct and responding in both tests is assumed to be at least partially determined by value, then an additional factor or factors must be affecting responding in at least one of the tests. We believe that such a factor is more likely to be present in the evocation strength test. Some authors (e.g., Rescorla, 1980; Williams, 1988) have noted that responding that is evoked or elicited by a stimulus is more variable and susceptible to factors that are extraneous to the arranged contingency, such as response topography and stimulus modality, than is responding that produces contingent reinforcement. For this reason, Rescorla (1980, p. 16) argued that the reinforcing power of a stimulus was often a better index of associative strength than its power to evoke responding. But in Experiment 2 the critical feature may have been that the stimuli presented simultaneously in the evocation strength test were each similar to a different baseline initial-link stimulus, whereas those in the reinforcing strength test were not. In that test, both choice stimuli were equally dissimilar from all baseline initial-link stimuli, but in the evocation strength test each stimulus was identical to one of the baseline initial-link stimuli (with the exception of the superimposed white Xs). Thus, any carryover of baseline switching patterns would affect relative responding in the evocation strength test but not in the reinforcing strength test, which could account for the discrepant results. By this logic, a replication of Experiment 2 that used terminal-link stimuli that were substantially different from those in the initial links should not find a discrepancy between the tests. However, this explanation may pose a new problem: Why would carryover be greater in the evocation strength test than in Experiment 1? Because the clearest shifts in dwell times in Experiment 1 were obtained with FI terminal links, carryover is perhaps less surprising with VI schedules. It is also possible that procedural differences may have affected the degree of carryover obtained in the two experiments, specifically (a) reinforcement versus extinc-

tion in the transfer test and (b) changeover versus two-key procedure. In particular, the discrimination between baseline and test in Experiment 1 may have been enhanced because position was a relevant cue in the transfer test, whereas it had been irrelevant within each baseline component.

However, it should be acknowledged that our explanation for the discrepancy between the results of the transfer tests is speculative. For example, it might be argued that responding in the evocation strength test was more, not less, sensitive to differences in stimulus value. If so, then perhaps the data in Experiment 2 are actually consistent with the view that value is a function of context. The problem with this interpretation, though, is that it requires the reinforcing strength test to be insensitive to differences in the values of the VI 20-s stimuli in T1, but relative responding clearly favored the VI 10-s stimulus over the VI 40-s stimulus in T2.

Thus, the data in Experiment 2, although orderly (except for Bird G10), underscore the fact that different transfer tests are not necessarily equivalent assays of stimulus value. Data for 3 subjects demonstrated strong control by scheduled delays to reinforcement in both reinforcing strength tests (T1 and T2), consistent with Experiment 1. However, for those same subjects responding in the evocation strength tests consistently favored the VI 20-s stimuli that had been the richer alternative in training. If stimulus value is a valid construct, we believe that the most likely explanation of these orderly but conflicting results is a carryover of baseline initial-link responding in the evocation strength tests.

GENERAL DISCUSSION

To investigate the relationship between stimulus value and reinforcement context, we conducted two experiments that employed different types of transfer tests with concurrent chains. In Experiment 1, two groups of pigeons were trained on multiple concurrent chains in which the terminal-link schedules in one component were FI 8 s FI 16 s (or VI 10 s VI 20 s) and in the other component were FI 16 s FI 32 s (or VI 20 s VI 40 s). After baseline training, the two FI 16-s (or VI 20-s) chains were presented together as a concurrent pair in test sessions. For all 4 subjects

with FI schedules and for 2 of the 3 subjects with VI schedules, the slopes of the dwell-time distributions changed in the first test sessions in the manner predicted if the values of the terminal-link stimuli were equal. Detailed analysis showed that for these 6 subjects, responding changed quickly in the very first test session, often in the first few cycles of exposure to the novel pair (see Figure 6). Experiment 2 used multiple concurrent chains with the same VI terminal links as Experiment 1. After baseline training, the relative reinforcing power of (a) the two VI 20-s stimuli and (b) the VI 10-s and VI 40-s stimuli was tested by making their presentation contingent upon responding in a novel initial-link situation. Consistent with the results of Experiment 1, relative responding in the reinforcing strength test was determined by the scheduled delays to reinforcement that had been signaled by the terminal-link stimuli in training. We also conducted an evocation strength test in which the ability of the two VI 20-s stimuli to elicit responding was compared. Here, the results were different: Relative responding during test favored the VI 20-s stimuli that had been paired with the VI 40-s schedule in training. Because the stimuli in the evocation strength test were similar to the initial links in baseline, however, it is reasonable to attribute the discrepancy with the results from the reinforcing strength test to a carryover of baseline response patterns.

Our experiments were designed to be concurrent-chains analogues of procedures used recently to assess stimulus value in concurrent schedules by means of transfer tests. In the first of these studies, Belke (1992) found that a stimulus associated with a VI 40-s schedule that had been a member of a concurrent pair with a VI 80-s schedule in training was preferred by 4:1 in a choice probe over a stimulus associated with an identical VI 40-s schedule but that had been paired with a VI 20-s schedule. He suggested that the value of a stimulus might be enhanced by its occurrence in a lean context of reinforcement (p. 402). However, Gibbon (1995) showed that Belke's results could be predicted accurately by a carryover to a test of switching patterns established in baseline, and Williams and Bell (1996) noted that such carryover implied that his results were actually uninformative regarding the determiners of stimulus value.

Because responding in the transfer test in Experiment 1 and in the reinforcing strength test of Experiment 2 was different from baseline, the present data are more readily interpreted as measuring the values of stimuli that had been established in baseline.

Overall, our data are most consistent with the view that the value of a terminal-link stimulus is independent of its context of reinforcement—specifically, that value is determined by the stimulus–reinforcer relation and is unaffected by the alternative terminal link in baseline. This conclusion supports models that interpret the effects of reinforcement context in terms of performance rather than learning, such as the contextual choice model (Grace, 1994) and scalar expectancy theory (Gibbon et al., 1988). Our data challenge alternative accounts, such as delay-reduction theory (Fantino et al., 1993), which maintain that value is a function of context.

The dwell-time distributions obtained for initial-link responding in Experiment 1 have the same general shape that Gibbon (1995) found with concurrent schedules: a sharp increase over short stays, followed by an approximately linear decrease, when plotted on semilogarithmic coordinates. The linearity indicates that dwell times in concurrent chains are exponentially distributed over that range. The strong similarity of the distributions supports one of the key assumptions of the contextual choice model: that concurrent chains may be viewed as a concurrent schedule of conditioned reinforcement, and that conditioned and unconditioned reinforcers are functionally equivalent in their effects on behavior (see also Williams & Dunn, 1991). In addition, according to the contextual choice model the effect of differential terminal-link value is analogous to unequal reinforcer magnitudes, and can be represented by concatenating ratios in the matching law (Baum & Rachlin, 1969; Davison, 1983). These assumptions make it possible to regard concurrent chains and concurrent schedules essentially as a single procedure that varies along several dimensions. It is then interesting to consider what dimension is responsible for the lack of substantial carryover during the transfer test in Experiment 1, compared with Gibbon's (1995) results. His procedure may be viewed as a concurrent chain in which the same contingent stimulus (i.e., the grain magazine

light) preceded food for both alternatives and in which the relative and absolute rates of stimulus presentation varied. Our procedure equalized the rates of stimulus (in this case, terminal-link) presentation but varied stimulus value by arranging unequal delays. There are five factors differentiating the experiments that could determine whether or not substantial carryover is observed: (a) grain magazine light or terminal links as the contingent stimuli, (b) relative and absolute rates of stimulus presentation, (c) differences in stimulus value, (d) whether different contingent stimuli were used for the alternatives, and (e) whether or not the contingent stimuli were presented in the transfer test. Of these, (b) is perhaps the most plausible candidate, and it is the important feature in Gibbon's (1995) analysis. If so, then varying, with concurrent chains, the relative and absolute rates of entry to equal-valued terminal links should produce results that replicate Gibbon's (which would also imply that using different stimuli was irrelevant). The importance of the other factors can also be tested. For example, the effect of differential terminal-link stimuli may be investigated by using grain magazine lights of different colors in concurrent schedules. It is also possible, of course, that some combination of these factors may be critical.

It is important, however, to emphasize that transfer tests are not pure assays of value, but are complex procedures in their own right. Experiment 1 showed that when chains were presented as a novel concurrent pair, varying degrees of carryover from baseline occurred for different birds. After a brief period of adjustment, relative responding was consistent with the hypothesis that the values of the stimuli were equal and hence independent of context, but the adaptation was not instantaneous. The transfer tests in Experiment 2 produced conflicting results, depending on whether the stimuli presented simultaneously in test were differentially (evocation strength) or nondifferentially (reinforcing strength) similar to baseline initial-link stimuli. At a minimum, then, it is necessary to stipulate that responding in a transfer test is determined both by stimulus value and hysteresis, and that the degree of hysteresis may depend on the similarity between the choice stimuli in test and baseline. Complexities of this sort

led Staddon, Davis, Machado, and Palmer (1994) to comment that transfer tests were "a poor way to assess the mechanisms of choice" (p. 710). However, the advantage of converging operations is gained by conducting multiple tests (Garner et al., 1956). To the extent that conceptualizing stimulus value as determined simply by the stimulus-reinforcer relation leads to a reasonably accurate and parsimonious account of the results from a variety of different transfer tests, confidence in the validity of that conceptualization of stimulus value as a construct increases.

That transfer tests are not pure assays of value becomes especially clear when they are described in general terms. Given a history of exposure to two situations, S1 and S2, the subject is exposed to a new situation, S3, containing stimulus elements of S1 and S2. Responding during S3 is then used to make inferences about the effects of prior exposure to S1 and S2. The dependent variable, typically, has been derived from the total number of responses made to stimuli in S3. However, assuming that changes in response rates in S3 are a continuous function of amount of training, some approach towards new asymptotic rates must occur, even if brief periods of exposure to S3 are interspersed with additional S1 and S2 training. For example, in a choice probe such as the evocation strength test in Experiment 2, response rates should eventually decrease to zero if the test continues long enough. It is an open question whether response totals or resistance to extinction (i.e., the rate of decrease in responding) is the better measure of stimulus value (Nevin, 1988). Although these measures are usually equivalent as long as merely ordinal comparisons are made, a parametric study could indicate which one produces the better correlation with baseline preference, and hence is to be preferred as a measure of stimulus value. Most generally, a complete account of responding in transfer tests will require solving the problem of how asymptotic response rates in choice situations are acquired (cf. McLean & Blampied, 1995). This task may seem daunting, but the payoff is a more complete understanding of both steady-state and dynamic choice behavior.

In conclusion, our experiments demonstrate the utility of transfer tests as a methodology for studying choice in concurrent

chains. They provide a rich source of data against which predictions of theoretical models can be tested. Overall, our results support the view that terminal-link value is determined by the stimulus-reinforcer relation independently of the alternative terminal link. Transfer tests should continue to play an important role in future research that not only explores the quantitative determiners of stimulus value but also aims for a complete description of choice behavior in transition as well as in steady state.

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